

DESIGN OF LUNAR BASE OBSERVATORIES

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Introduction

In this paper, several recently suggested concepts for conducting astronomy from a lunar base are cited. Then, the process and sequence of events that will be required to design an observatory to be emplaced on the Moon are examined.

Background

In the 21st century, a lunar base will be established which will eventually support astronomical observations from the lunar surface. Several nations and groups of nations will have the capability to advance space colonization beyond Earth orbit. Mankind will return to the Moon, and, when we do, eyes will turn skyward. Man will seek the means to make the best possible use of the characteristics and the environment of the Moon that provide such an excellent platform for astronomical observations.

Observatory Options

Many astronomical observatory concepts and instrument configurations have been suggested for use on the lunar surface. At recent workshops and conferences, the concepts have been discussed in increasing detail (refs. 1 to 4). Additional concepts were suggested and discussed at the NASA-sponsored workshop on Astronomical Observations From a Lunar Base, held in Houston, Texas, in January 1986.

Each observatory concept has its own set of advantages, constraints, and cost drivers. Each requires a different mass of material and effort to be expended on the lunar surface. For each concept, there is an anticipated return in knowledge.

A Moon-Earth radio interferometer (MERI) has been suggested (ref. 2) which could begin with a 10- to 15-m-diameter antenna on the Moon. This antenna, functioning with antennas on Earth and possibly in Earth orbit, would achieve resolution (at the 6-cm wavelength) 30 times better than the proposed Very Long Baseline Array and 10 000 times better than the existing very large array (VLA). Progression would then be to larger or multiple antennas on the Moon.

Another suggested instrument for installation on the lunar surface is a very low frequency (VLF) radio telescope (ref. 3) to investigate the now largely inaccessible radio sky in the 10-m and longer wavelengths. Terrestrial ionospheric absorption prevents terrestrial observations in these wavelengths. This VLF radio telescope would consist of a central computer facility and many short wires, each equipped with an amplifier and a digitizer, laid on the lunar surface over an area of approximately 15 by 30 km.

Optical interferometers capable of resolution approaching 1 μ arcsec may be feasible on the Moon. Burke (ref. 4) suggests a Y-shaped array of twenty-seven 1-m optical telescopes linked to a central correlation station through a set of variable time delays. Each arm of the Y would be 6 km long.

Other concepts proposed include a very large Arecibo-type telescope, sets of instruments for x-ray and gamma-ray astronomy, infrared astronomy, search for extraterrestrial intelligence (SETI), and observations from possible permanently shadowed zones in craters near the lunar poles. Some design considerations for four observatory options follow. For each option, there are common design considerations, such as making use of lunar materials (e.g., for shielding in the near term and for manufacturing composite structural materials in the far term), minimizing mass to be transported from Earth, packaging for transport, and reducing erection complexity.

1. MERI — parabolic dish radio antennas

- a. Site selection and characterization
- b. Thermal strain rates at sunrise and sunset
- c. Sunshield
- d. Foundation excavation and placement
- e. Foundation dynamics
- f. Breakdown into transportable packages with semiautomated erectability
- g. Shielding for electronics and other vital operations

2. VLF radio telescope — wires on surface over a large area

- a. Site selection and characterization
- b. Capability to traverse large area and place wires
- c. Erection and shielding of a control facility

3. Optical interferometer

- a. Site selection and characterization
- b. Control capability (stringent requirements limiting differential settlements, tide compensation)
- c. Location of a suitable site for 6-km-long rails laid out on lunar surface
- d. Dynamic response of lunar rubble to movement of telescopes

4. Arecibo-type radio telescope
 - a. Selection of existing crater
 - b. Rim-to-floor transportation
 - c. Tension and shear-resisting anchors for cables
 - d. Foundation elements and support structure
 - e. Design for thermal strain compensation

Advantages of the Environment

The features of the lunar environment that are inviting to astronomers are the large, stable platform (with a relatively benign seismic environment), the extremely tenuous atmosphere, the possibility of uninterrupted observations for 14 days, and (on the far side) the avoidance of earthshine and radiofrequency interference of terrestrial origin. Also of significance is the lower acceleration due to gravity (one-sixth terrestrial). There is ample material for shielding and, during the night (and at the lunar poles), an environment advantageous to keeping detectors at their required low temperatures.

The Design Process

Some issues (not in order of importance) to be resolved in the process of designing an astronomical observatory for the lunar surface are type of observatory, operational function of lunar observatory, collectors/sensors/controls, sites and site characterization, observatory/regolith interface, materials for fabrication, positioning/construction, development process, data management system, life-cycle servicing, observatory/infrastructure interface, and shielding. The type of observatory can be selected after enough is known about each proposed concept to be able to quantify the mass required on the Moon, the effort to emplace, and the scientific return. Because the suggested concepts need more development and some effort toward optimizing, quantification is not feasible currently.

When each viable observatory alternative has been brought to sufficient design maturity, it will be evaluated fairly for priority placement on the Moon. The approach to be initiated for each alternative consists of determining expected increase in knowledge, investment cost, and assembly effort; comparing alternatives on the basis of the determinations; and arriving at possible time-phasing for development of each alternative. Questions then to be asked include

1. What is the "right" development sequence for each observatory concept?
2. Given an agreed-to development sequence,
 - a. What are the technical requirements?
 - b. What are the issues to be resolved?
 - c. What are the development steps?

To obtain a fair, unbiased comparative ranking of design solutions for a Moon-based observatory and to identify all alternative solutions, the approach should include the following steps.

1. Perform tradeoff and optimization studies to place each concept in its most competitive position.
2. Be alert to alternative component combinations that yield better design solutions.
3. Identify areas requiring experimental results or technological development.
4. Identify costs and risks associated with each alternative.

The goal is to provide a traceable path to the best design solution for a lunar astronomical observatory and to get an estimate of life-cycle cost. Testing will be done to provide design data, to verify mathematical models for observatory performance, and to investigate critical behavior characteristics. Extensive facilities and resources are required for test and evaluation of space systems (ref. 5). Results of tests will enable verifying designs and identifying problem areas to be corrected. Essential test and evaluation resources must be planned and developed.

The design process for a lunar observatory is shown in figure 1. We are now in "the 'thinking' and gathering of ideas phase" for an astronomical observatory on the Moon.

Twenty years ago, Herbig and others (refs. 6 and 7) suggested the telescope shown in figures 2 and 3 with the portrayed erection sequence. Today, we think in terms of adaptive optics and interferometric arrays. By early in the 21st century, the observatory system design process should arrive at one or more promising concepts from which a "best" solution can be established. A prototype can then be built and tested. Satisfactory design solutions should be ready for emplacement on the Moon by about 2010. Telescopes take a long time to develop. Development of the Hubble Space Telescope has required more than 20 years. Studies should be initiated now to define a lunar-based set of astronomical instruments and experiments for the year 2010. Our knowledge of the Moon from previous expeditions will be very useful in the design process (refs. 8 and 9).

References

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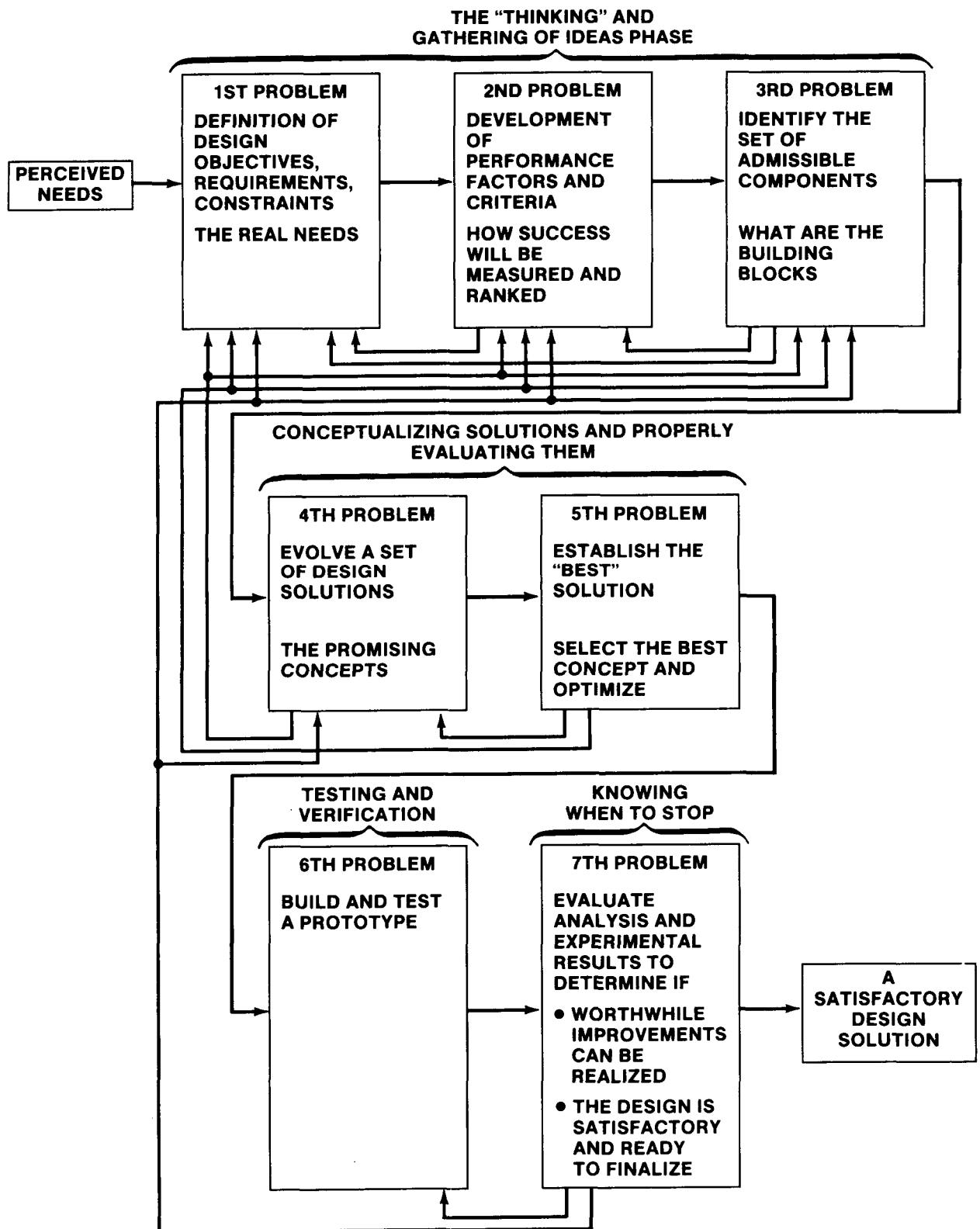
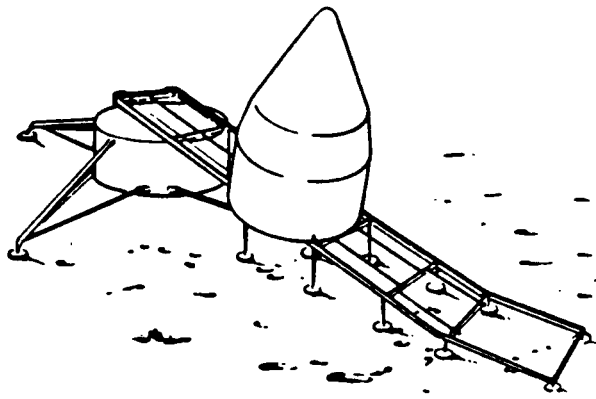
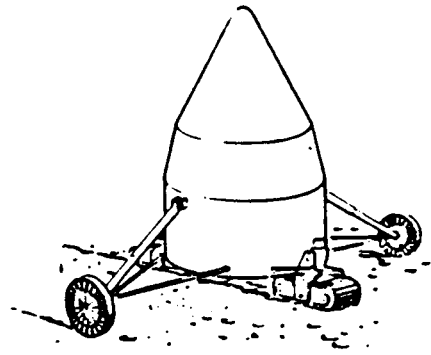


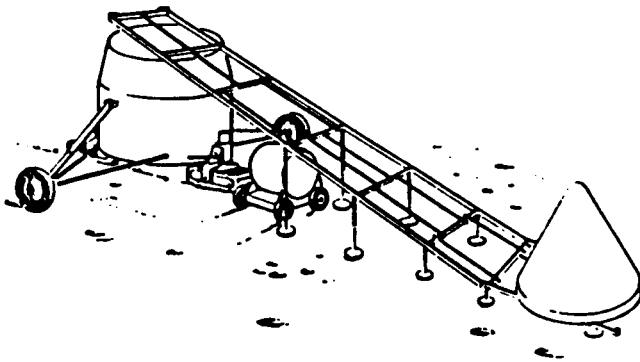
Figure 1.- The system design process (the seven problems of design).



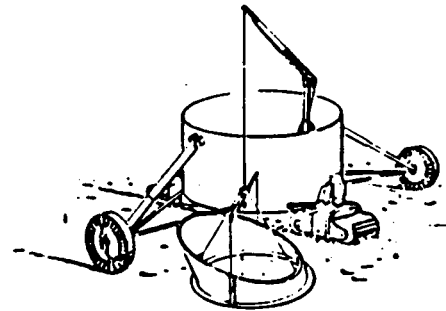
**UNLOAD FROM LUNAR
LANDING VEHICLE**



**TRANSPORT TO OBSERVATORY
SITE**

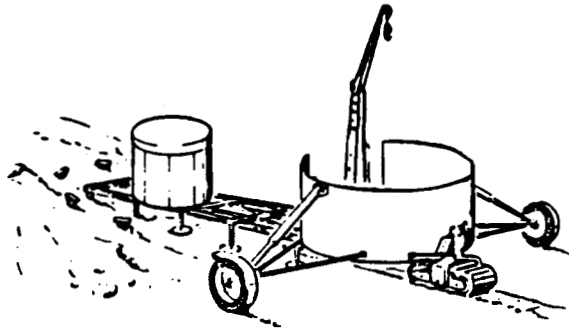


**DEPLOY PRIMARY MIRROR SYSTEM
AND INSTRUMENT ROOM**

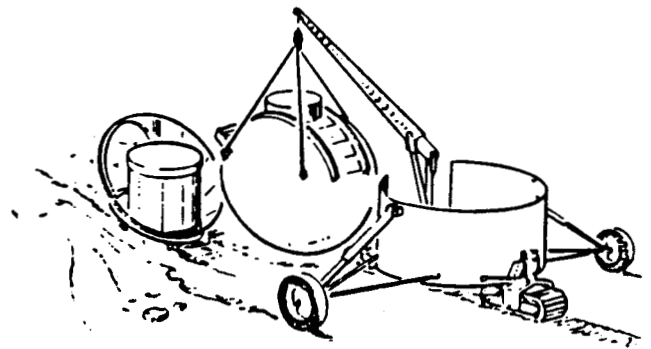


**UNLOAD COMPONENTS
WITH DAVIT**

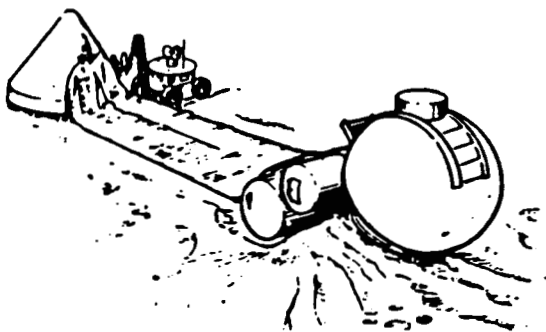
Figure 2.- Deployment of 100-in. horizontal telescope, part I.



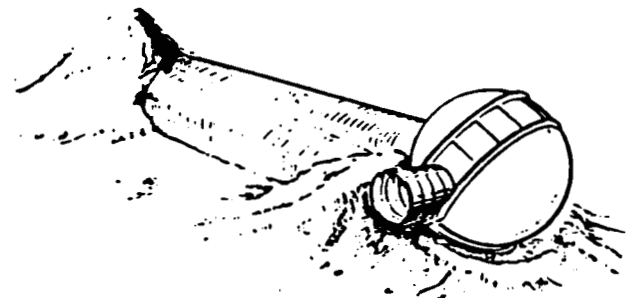
UNLOAD 200-IN. SIDEROSTAT



INSTALL DOME SEGMENTS



DEPLOY INFLATABLE TUNNEL



**ALIGN OPTICS;
ACTIVATE AND CHECK OUT**

Figure 3.- Deployment of 100-in. horizontal telescope, part II.